Modeling and Simulation Initiatives For DoD Force Protection

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Abstract
Sandia National Laboratories is currently exploring opportunities to apply its modeling and simulation (M&S) capabilities to support a wide spectrum of DoD needs. Joint Vision 2010 served as the template for five different M&S thrust areas. One of the operational concepts of JV 2010 is Full-Dimensional Protection which is the control of the battlespace to ensure freedom of action during deployment, maneuver and engagement, while providing defenses for forces and facilities. From this concept we have identified a number of force protection needs and are evaluating Sandia M&S tools and concepts in relation to these needs. Within the trust area of force protection we have identified a number of M&S opportunities. They include risk analysis and vulnerability assessments using tools such as HAMER (Hazard Assessment and Mission Enhancement of Resources) and other force protection database and management systems. For the Chem-Bio threats, work is ongoing to model dispersion of airborne chemical/biological agents in relatively open areas and also in complex structures. Models have also been developed to simulate the blast response by structures. Other areas include the use of physics-based modeling and simulation methods, intelligent adaptive algorithms and cognitive engineering to develop predictive tools, global optimization of problem solutions and advanced learning methods. This paper will briefly discuss some of the M&S capabilities and opportunities to meet DoD force protection needs.

Modeling and Simulation (M&S) at Sandia
Historically M&S supported experiments and proof of concept tests. Initial applications at Sandia focused on nuclear weapon design. Now Sandia has much wider applications, which include robotics, microelectronics, biomedical and technology integration. Today and in the future, M&S forms stand-alone products in such areas as integrated system design, training, decision-making, mission planning, information and physical security, infrastructure protection and analysis in chemical, biological, radiological and blast effects. Listed below are some of the many and diverse areas of M&S within Sandia.

- Physics And Fundamental Phenomenology Models
  - Models based on the fundamental relationships of physics and that describe basic physics and/or fundamental physical phenomena
- Engineering Tools For Performance Evaluation
  - Simulations used by design engineers to understand and predict engineering performance
- Product Life Cycle Engineering Tools
  - Simulations that represent major elements of hardware lifecycle other than engineering performance in the mission environment
- Simulation Of Integrated Systems, Phenomena, Structures
  - Tools for the analysis of integrated systems and macro-scale phenomena
- Synthetic Environments
  - Simulations and models that provide a representation of the real world in a form that can be used in lieu of the real world in operation of a component/subsystem/system or during operator activities

- Computing Environments
  - Hardware, software, hardware/software combinations that provide an environment for efficient M&S development/operation or facilitate M&S use in some phase of the product lifecycle
- M&S Verification, Validation And Experimental Operations
  - Models, simulations, computer tools, and methodologies that support the V&V of simulations and/or support experimental operations

Five thrust areas in M&S have been identified for strategic support and partnering with DoD. They are:

- Thrust A. Simulation Driven Concept Exploration
- Thrust B. Simulation-Based Design, Test, Evaluation
- Thrust C. Force Protection Simulation & Analysis
- Thrust D. Predictive M&S For Sustainment Logistics
- Thrust E. Simulating Comprehensive Battlefield Connectivity

The remainder of this paper will discuss some of the activities for thrust area C which concerns force protection. The focus in this area is to provide an integrating framework to transition from "vulnerability assessment" to "situational awareness".

Thrust Area C: Force Protection Modeling, Simulation and Analysis

There are a large and diverse number of elements being addressed within this area. The following lists some of those elements:

- System Level Security/Force Protection Models and Analysis Tools
  - Examples: DEPO, ASSESS, HAMER, JTS/JCATS
- Architectural Surety and Infrastructure Modeling, Simulation, and Analysis
  - Subject Matter Expertise in Applying Computational Methods to Protection of Buildings and Facilities from Blasts, Other Threats
- Plume Transport Models
  - Examples: ERAD
- Aerosol Transport In Enclosed Environments
  - Novel Computational Methods to Address C-B Threats
- Intelligent Algorithms
  - Epidemiological Predictions
  - Neural Net Simulation Methods to Detect Indicators of Bio Attack
- Virtual Reality Environments For Training And Mission Rehearsal
  - Examples/Training: VRaptor, BioSimmer, MediSim
  - Examples/Mission Planning & Rehearsal: COVRIP
- Probabilistic Risk Assessment Tools and Fault Tree Analysis

Security/Force Protection Models and Analysis Tools. A number of tools exist for performing vulnerability and/or risk analysis for facilities and infrastructure. These tools are based on the DEPO (Design Evaluation Process Outline) approach developed at Sandia. ASSESS (Analytic System and Software for Evaluating Safeguards and Security) is a vulnerability assessment tool developed for the Department of Energy by Sandia and Lawrence Livermore laboratories. For the outsider module it allows the user to define the safeguards system using an adversary sequence diagram (Figure 1), perform adversary path analysis and determine the probability of interruption of an adversary attack. ASSESS is supported by a comprehensive database which provides performance tested values for detection and delay for many protective elements. DOE will be funding an update and expansion of ASSESS's capabilities starting in FY01. HAMER (Hazard Assessment and Mitigation of Resources) was supported by the U.S. Airforce Force Protection Battlelab and provides the commander a prototype tool to evaluate risk using a systems approach to make informed, prioritized, force protection decisions. HAMER also includes a similar database to ASSESS, the ability to display the site infrastructure and protective systems on a map, calculate risk, perform baseline and what-if analyses, a top-level blast effects analysis capability (Figure 2) and to show commanders summary overview slides. JTS (Joint Tactical Simulation) allows the user to simulate force-on-force engagements using the site maps and to determine the probability of neutralization.

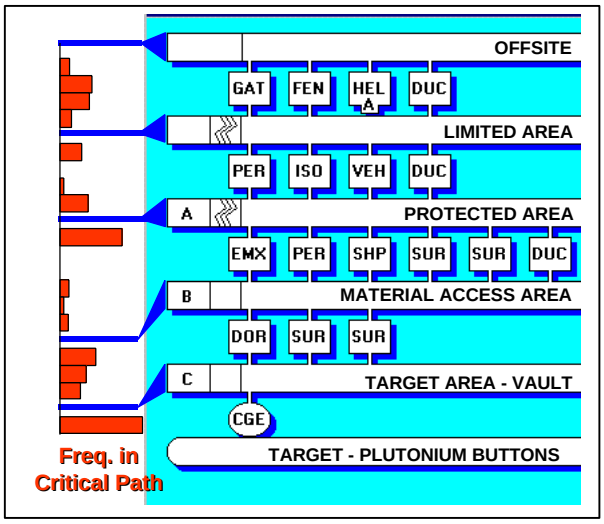

Figure 1. Adversary Sequence Diagram from ASSESS

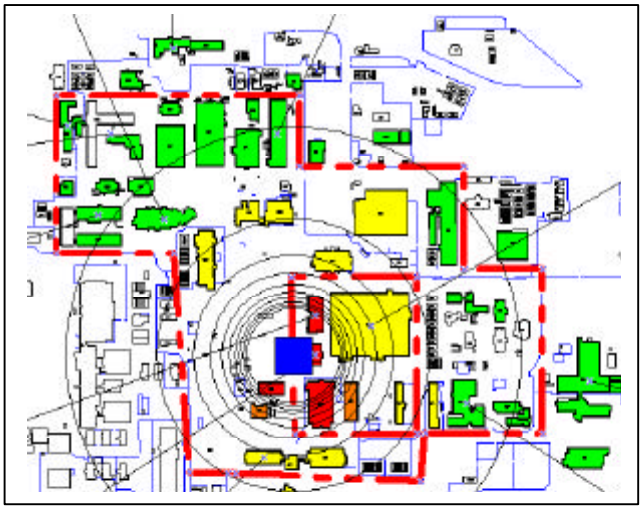

Figure 2. Blast effects from HAMER

Architectural Surety and Infrastructure Modeling, Simulation, and Analysis. Using a model known as Pronto 3D structures can be explicitly modeled using a Lagrangian formulation, which is vastly superior over Eulerian, for predicting structural response. This model uses Sandia's massive parallel processing computers. For example, to model one bay of a two story building requires 5 million elements and the power of approximately 2,000 processors. PROTECT (Infrastructure Protection Demonstration) is a DOE and internally funded program to demonstrate system concepts for protecting critical infrastructure against C/B attack. Shown in Figure 3 is the representation of the effects on a bay from 1000 pounds of explosives.

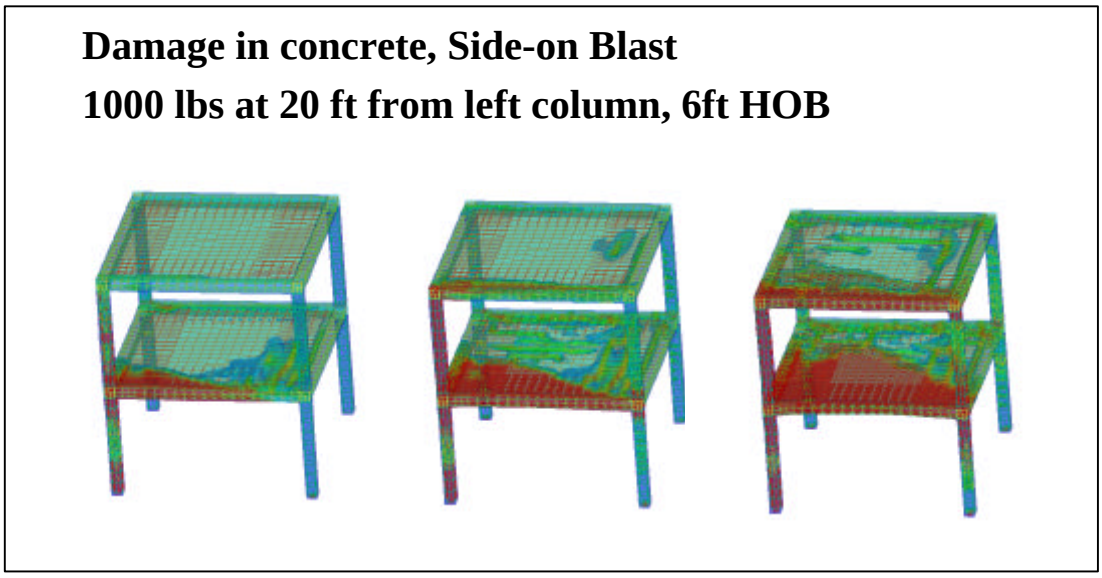

Figure 3. Simulated effects from a blast to a concrete bay

Plume Transport Models. ERAD (Explosive Release Atmospheric Dispersion) provides real-time predictions of the hazards which result from explosive, fire, and non-buoyant releases of toxic materials in the atmosphere. ERAD is a three-dimensional numerical simulation of atmospheric transport and diffusion. It operates on a Laptop PC or workstation compute platform and typically has an execution time of less than one minute. It uses integral technique for source buoyancy and probabilistic approach for dispersion. ERAD capabilities have been extended to toxicology and calculation of consequences for CB scenarios. ERAD can determine contours for exposure levels on maps for GA, GB, GD, GF, VX, HD, Anthrax, Tularemia, Brucellosis, Q Fever, Plague VEE, Botulin, SEB, Ricin, and Saxitoxin. Probit information and population distribution is used to calculate the number of fatalities and number of injuries for the above agents. In addition, different quantitative response for general population and soldiers

Aerosol Transport In Enclosed Environments. Using a program known as CONTAIN a capability has been developed to model indoor transport of CB agents within buildings. The program utilizes structural drawings and building air movement features to model the dispersion of CB agents within structures. The tool was used to model the Albuquerque Federal Courthouse. Shown in Figure 4 is the dispersion of a chemical agent on just one floor of the courthouse. It can be used to model dispersion of CB agents, optimize placement of possible sensors and support decision makers for facility response.

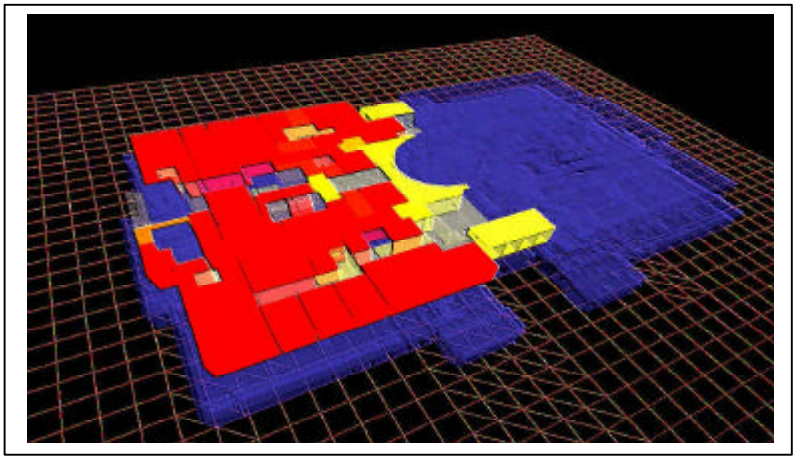

Figure 4. Dispersion of Chemical Agent inside a building

Intelligent Algorithms. Intelligent algorithms are specialized versions or hybrids of multivariate analysis, genetic, neural net, simulated annealing and particle-in-cell algorithms. A number of different intelligent algorithms are being used for the modeling and detection of terrorist events. They include modeling and detection of disease outbreaks by identifying non-obvious indicators and detection of exposure to CB agents. Genetic algorithms are used for global optimization to include the simulation and modeling of autonomous agents in such applications as sensor integration and 2-D and 3-D simulations of collective behavior of swarms of elements. Neural nets are being used to solve complex problems and particle-in-cell (PIC) has been used to model swarm behavior (Figure 5). Finally, utilizing a number of these intelligent algorithms to create a behavioral toolbox as well as individual and group behavior models, work is being done to simulate human behavior in complex adaptive systems.

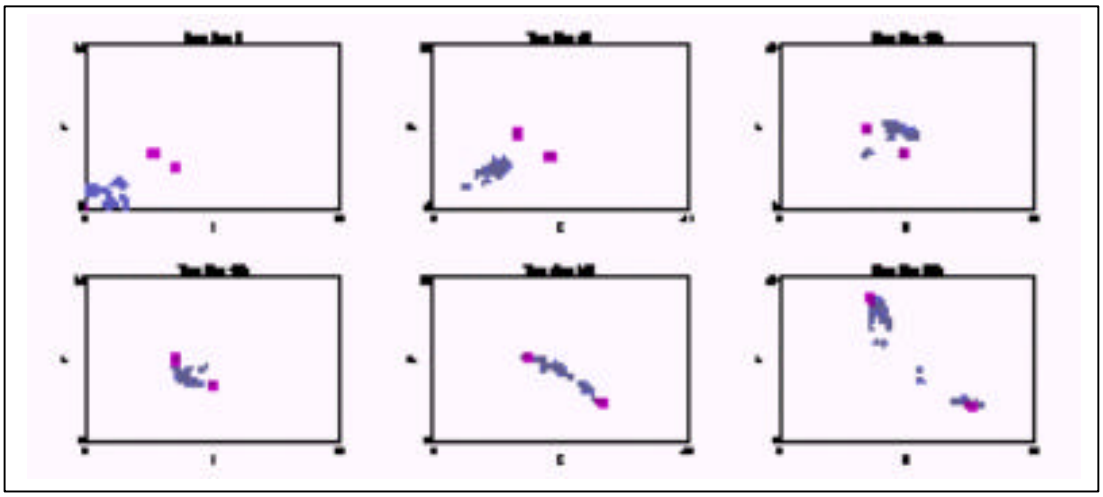

Figure 5. PIC technique to model swarm dynamics

Virtual Reality Environments For Training And Mission Rehearsal. A number of current applications are being developed which utilize virtual reality (VR) in the areas of training and rehearsals. BioSimMER provides a realistic VR training environment for CB first responders. It is a physically based VR training environment that simulates casualty response and reacts to responder intervention. The casualty provides a physiological response to the agent and treatment and the responder performs interactive triage, diagnosis, and treatment. Other areas include the ability for people to simulate hostage rescues and small force-on-force engagements. Finally, some development has been done to enhance small unit rehearsal scenarios.

Probabilistic Risk Assessment Tools and Fault Tree Analysis. The use of probabilistic risk assessment (PRA) tools and fault trees (Figure 6) are being used in a number of applications associated with infrastructure protection. In some cases the DEPO approach has been modified to better meet the requirements for civilian infrastructure targets.

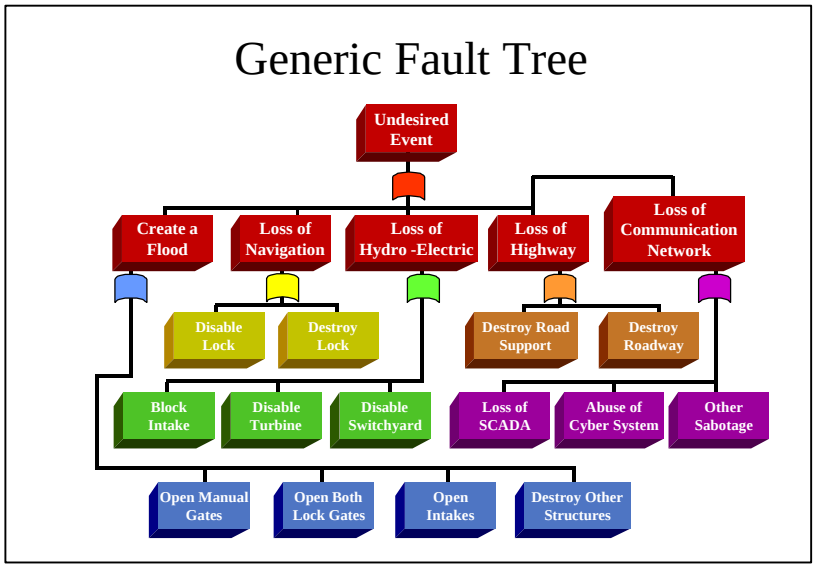

Figure 6. Fault Tree

Summary

Sandia has developed a number of different M&S tools that can be applied to the area of force protection. Some of these tools involve very complex and numerous calculations which must be run on large computer systems while other tools can operate on a laptop PC. In almost all cases tools currently exist which can be used to support a current identified requirements. Many of these tools are physics-based tools or are supported by databases developed from extensive testing. Sandia is looking for opportunities to apply it's considerable M&S experience and capabilities to help DoD not only in the area of force protection but also in other areas.

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